Transmission of electrons inside the cryogenic pumps of ITER Neutral Beam Injector

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The conversion of fast ions to neutrals and their injection in magnetically confined plasmas is fundamental to increase the particle energy and enhance the fusion process. In advanced fusion devices the use of negative ions is necessary, due to their high neutralization yield in collisions with a gas target even at particle energy around 1MeV. This feature is exploited by interposing along the negative ion beam path a neutralizer, i.e. a component where a flux of neutral gas is steadily injected. On the open sides of the neutralizer the gas leaks out, determining beam losses (by stripping inside the accelerator or re-ionization of neutrals after the neutralizer) that should be limited as much as possible.

The opposite requirements of high gas density in the neutralizer and low density elsewhere in the accelerator and the beamline determines huge requirements for the pumping system; cryogenic pumps are a standard choice in nowadays neutral beam injector. In such pumps particles are trapped on the active surfaces of the pump, kept at liquid helium temperature and combined with the use of highly sorbing materials such as activated charcoal.

In the ITER NBI beamline, 8x2.5 m2 cryogenic pumps are installed on either side of the beamline vessel, for a total pumping speed of 5000 m3/s in hydrogen and an expected background pressure down to 10-3 Pa in the vessel [1] during the beam-on phase. The charcoal active surfaces are shielded from any source of direct heat (radiation from other components or high energy secondary particles); nonetheless, stray electrons may overcome those barriers by multiple bounces and compromise the pump operation. Their contribution to the overall efficiency of the cooling plant was never verified but it is necessary to assure the proper operation of the pumping system, especially during long beam pulses.

In this paper we present a simulation of the electron propagation of the electrons inside the pump. A general electron transmission probability has been calculated by simulating a uniform distribution of electron, and following their trajectories in one of the 16 periodic modules of the pump, taking into account their geometry and the local magnetic field. The resulting transmission probability, depending on the initial position, angle, and energy of the particles has been applied to project the starting distribution of electrons entering the pumps (calculated a priori with beam transport models described elsewhere [2,3]) on the critical panels, to obtain the power load on the active surfaces of the pumping system of ITER NBI and its test facility MITICA.

References

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